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The compelling case to adopt and/or transition to LTE Band 41 in the 2.6 GHz spectrum band in Asia and globally

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Windsor Place Consulting Pty Ltd ('WPC') is internationally recognised as an outstanding provider of advice to the information industries. The firm, established in 2000, works extensively in telecommunications, media, and information technology, both in the development of commercial strategies for the private sector and the formulation of national policy and legislative settings for public sector clients. WPC's team members have a long association with these industries, having been actively involved through various stages of market liberalisation, from the introduction of competition in Australia in the 1990's to the drafting and implementation of modern convergence legislation in a range of countries especially in Asia, Africa and the Pacific.

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1 Executive summary

There are compelling reasons to allocate additional International Mobile Telecommunications (IMT) spectrum including the 700 MHz, 2.3 GHz, 2.6 GHz and 3.5 GHz bands and mmWave spectrum in markets where they have not yet been allocated, and if they available, for 4G and future 5G mobile usage as soon as practicable.

While much could be said about the urgent need for Governments and national regulators to increase total allocated IMT spectrum to meet sector demand, this paper has a more singular focus. A particular goal. Its' sole concentration is on the 2.6 GHz spectrum; this key capacity spectrum band is the largest single band of IMT spectrum band below 3 GHz.

In respect of the 2.6 GHz spectrum band, given the need for increased bandwidth supply in Asian and global markets and given rapidly increasing video consumption by mobile users, this spectrum band should be available for use as soon as practicable. It is, however, not enough to just make the 2.6 GHz band available – ***optimally it should be made available for use by endorsing the TDD configuration of LTE Band 41*** instead of the alternative hybrid FDD/TDD configuration of LTE Bands 7/38.

Key reasons to adopt LTE Band 41

Adopting TDD for the entire 2.6 GHz band has a range of significant benefits *inter alia*:

- The *shift from FDD to TDD technologies will enable better matching of current upload and download use patterns* which are likely to become more asymmetric over time. Optimising frequency spectrum for use has significant economic benefits;
- *TDD supports the use of new techniques such as massive MIMO technologies* which offer around five times better spectrum utilisation. Spectral efficiency should be at the core of spectrum management decisions by Governments and regulators in relation to IMT spectrum;
- *Elimination of the need for 10 MHz of spectrum to be used as guard bands in the band*. This is not insignificant (approximately 5 percent of the band) in the context of ongoing IMT spectrum scarcity especially in spectrum below 3 GHz;
- The *LTE Band 41 network deployment will result in lower per MB/GB costs for MNOs and hence makes compelling commercial sense for MNOs in the context of relatively low Asian monthly ARPUs.* Such lower costs will allow more affordable retail tariffs which is a regional Government policy objective;

- As *historically unpaired/TDD spectrum has been priced below paired FDD spectrum on a per MHz basis in spectrum auctions, there are likely to be benefits for industry for the adoption of LTE Band 41. There are also benefits for regulators and Government in allocating/auctioning a homogenous block of 190 MHz spectrum* rather than attempting to sell hybrid spectrum allocations. *Importantly, larger block sizes of up to 100 MHz would improve integrated 4G+5G investment efficiency (by allowing say 40 MHz to be allocated for TDD LTE and 60 MHz for 5G) and this fact should be considered by regulators in their allocation decisions*;
- *The allocation or spectrum auction of a single 190 MHz TDD block strongly supports sector competition by enabling the allocation of efficiently sized blocks to around 3 to 5 MNOs* (for example, three lots at 50 MHz and one lot at 40 MHz or three allocations of 40 MHz to the MNOs in a market plus 70 MHz which can be contested in any auction). Such lot sizes, while not optimal (100 MHz is optimal in the 5G context), are more than sufficient to provide future 5G services in this band; and
- *TDD configuration of the 2.6 GHz band enables transition to 5G at lower capital cost and therefore enables more Asian and global consumers to participate in the upcoming 5G revolution*. They can also participate sooner. In markets where the first 5G spectrum band – the 3.5 GHz spectrum band – is not available in the near term because it is currently allocated to satellite services and cannot be shared, the 2.6 GHz band is an alternative 5G band.

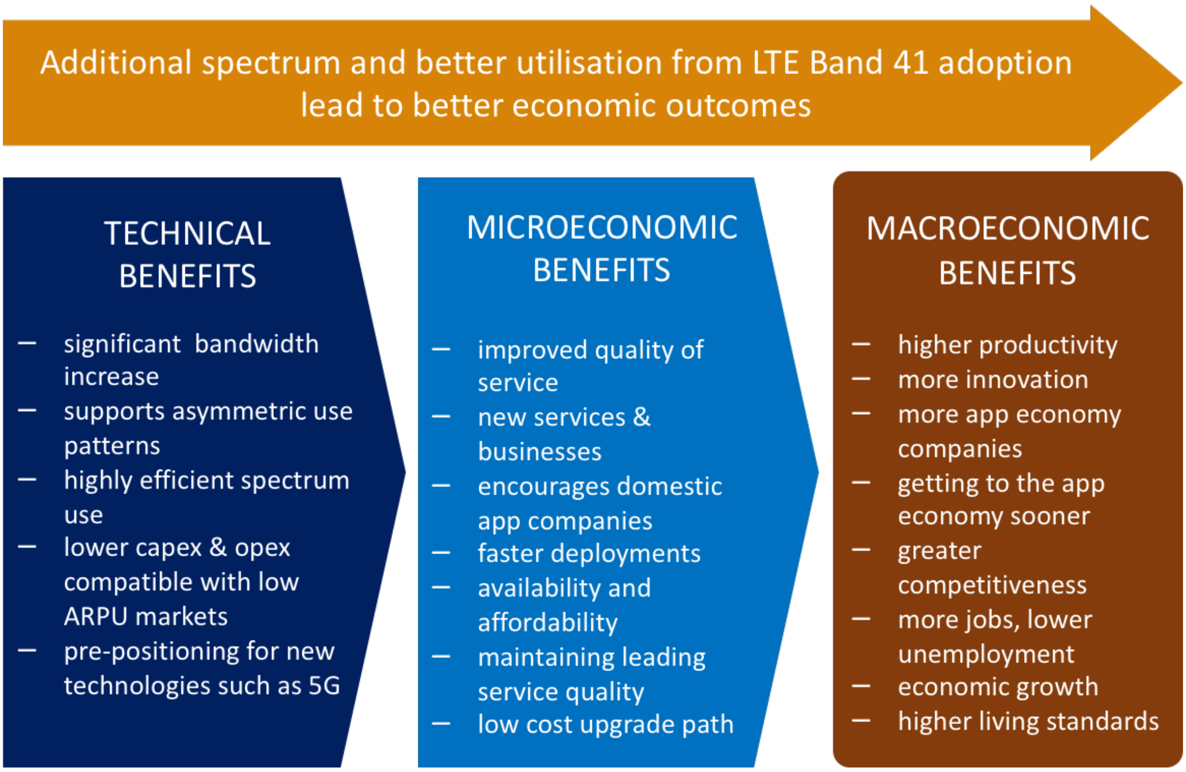
Given the above, **there is a compelling case for policy makers, regulators and MNOs to adopt and/or transition to 3GPP Band 41 in Asia and globally in relation to the 2.6 GHz band in preference to other band configurations as soon as their regulatory and market conditions permit.**

The technical advantages of LTE Band 41 in the 2.6 GHz band as described, leads directly to a set of compelling economic benefits that are of particular value in emerging economies.

Mobile spectrum is the economic life-blood of both emerging and developed economies. It is a critical input for more efficient markets and for the business innovations associated with the App economy. The benefits of more mobile bandwidth begin at the level of individual industries and markets (the microeconomic level) as improvements in communications and data services flow through to greater productivity and the creation of new businesses. This creation of new jobs, new businesses and new sources of wealth will accumulate across industries and lead to better macroeconomic outcomes such as faster economic growth and job creation, lower unemployment and greater income per capita.

High quality mobile communications services should be regarded as a form of national infrastructure without which economic development is likely to be highly constrained. Exhibit 1 shows the micro and macroeconomic benefits of increases in spectrum, its efficient use, and the benefits over time of minimising future upgrade paths to new technologies and standards, such as those which arise from adopting LTE Band 41.

Exhibit 1: Summary of the economic benefits of deploying LTE Band 41



2 Introduction and Background

2.1 Overview

Spectrum is the essential element of the global mobile industry and at a policy level is key to the provisioning of affordable wireless broadband services to all consumers. While any spectrum is desirable, all spectrum isn't equal. There are compelling reasons to allocate additional IMT spectrum including the 700 MHz, 2.3 GHz, 2.6 GHz and 3.5 GHz bands and mmWave spectrum in markets where they have not yet been allocated, and if they available, for 4G and future 5G mobile usage as soon as practicable.

The quantum of spectrum issued to MNOs will determine whether they have the bandwidth required to handle the increasing traffic volumes generated by rising demand for mobile broadband, while continuing to deliver high-quality services to their customers. Ideally, MNOs need a portfolio of low-frequency (below 1 GHz), medium-frequency (1 to 6 GHz) and high-frequency (above 6 GHz) spectrum as different types of spectrum are better-suited to different purposes given their propagation characteristics and spectrum availability.

While much could be said about the urgent need for Governments and national regulators to increase total allocated IMT spectrum to meet sector demand, this paper has a more singular focus. A particular goal. Its' sole concentration is on the 2.6 GHz spectrum; this key capacity spectrum band is the largest single band of IMT spectrum band below 3 GHz.

In respect of the 2.6 GHz spectrum band, given the need for increased bandwidth supply in Asian and global markets and given rapidly increasing video consumption by mobile users, this spectrum band should be available for use as soon as practicable. It is, however, not enough to just make it available – optimally it should be made available for use by endorsing the TDD configuration of LTE Band 41 instead of the alternative hybrid FDD/TDD configuration of LTE Bands 7/38.

2.2 Structure of this Paper

The structure of this Paper is straight-forward, comprising 4 parts focussing on why LTE Band 41 (TDD) is optimal band configuration for the 2.6 GHz spectrum band, as follows:

- Why LTE Band 41 is optimal for Asia and globally (see Section 3);
- Optimal deployment of LTE Band 41 networks (see Section 4);
- The economic benefits arising from allocating the 2.6 GHz spectrum and adopting LTE Band 41 (see Section 5); and
- Conclusions and Recommendations (see Section 6).

3 Why LTE Band 41 is optimal for Asia and globally

3.1 Overview

The ITU identified the medium frequency spectrum 2500-2690 MHz (or the 2.6 GHz spectrum band) as a global band for IMT and it was formally included in the *Radio Regulations* in accordance with Resolution 223 (Rev.WRC-15).[1] Importantly, this frequency band is available globally across all three ITU regions.

The ITU, in *Recommendation ITU-R M.1036-5 (10/2015)*, has defined three alternative channel arrangements for the 2.6 GHz band plan, as detailed below and as shown in Exhibit 2 over:

- ***ITU Option 1:*** Preconfigured allocations of paired (FDD) and unpaired (TDD) spectrum - 2x70MHz for FDD and 50MHz for TDD;
- ***ITU Option 2:*** Paired spectrum only, with the uplink portion of some pairs in another undetermined band; and
- ***ITU Option 3:*** Flexibility – licensees/regulators can decide how to allocate the spectrum they acquire to paired (FDD) or unpaired (TDD) operation. [2]

The ITU Option 1 band plan was widely adopted in Europe following a recommendation from the European Conference of Postal and Telecommunications Administrations (CEPT).[3] It was also originally supported by the GSMA.

In Asia, Singapore (which licensed the band in May 2005), Hong Kong (October 2008), Malaysian (2013)[4] have followed an approach aligned with the same band plan.

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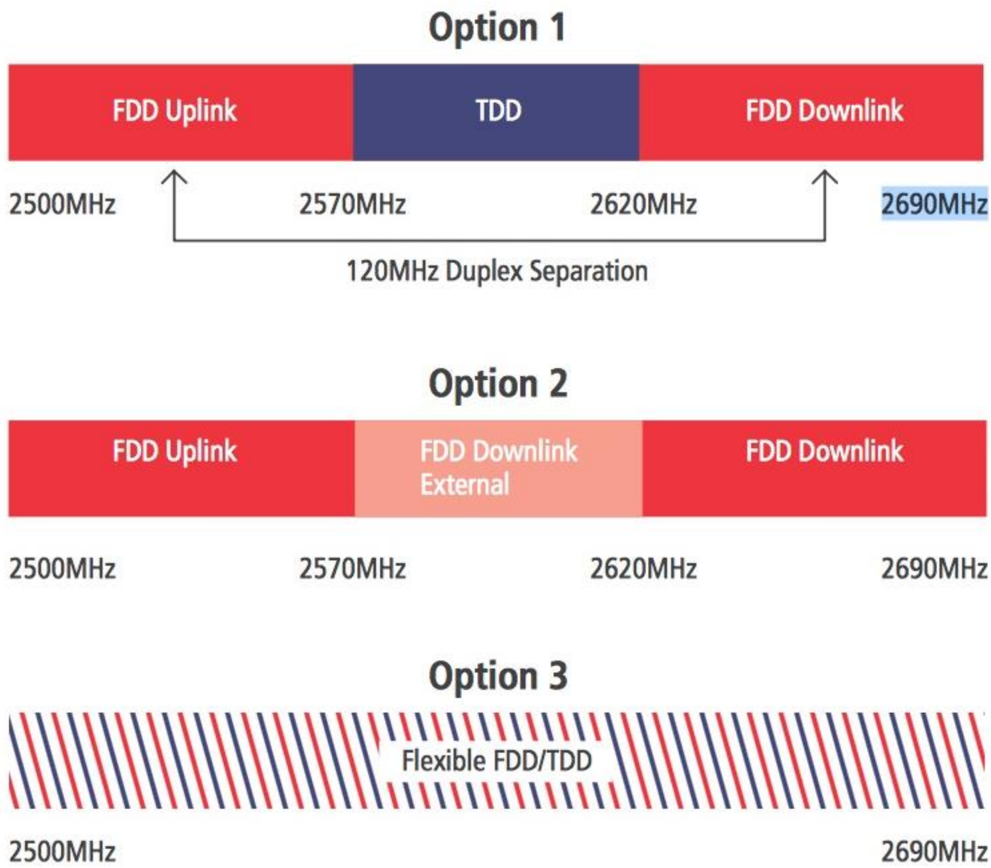
1 Refer to ITU, *Radio Regulations, (2016),* Footnote 5.384A

2 Until now, global regulators and the industry have focused primarily on Options 1 and 3. Option 2 can largely be disregarded, as there is little evidence of demand from MNOs to use the centre band for FDD downlink.

3 CEPT Electronic Communications Committee (ECC) reference ECC/ DEC/(05)05; and the Commission of the European Communities decision of 13 June 2008 reference 2008/477/EC

4 MCMC, Standard Radio System Plan, *Requirements for International Mobile Telecommunications (IMT) Systems operating in the Frequency Band 2500 MHz to 2690 MHz,* SRSP-523, 28 November 2012

Exhibit 2: Channel Arrangements for the 2.6 GHz bands



Source: GSMA, The 2.6GHz Spectrum Band, An Opportunity for Global Mobile Broadband, page 12

Since 3GPP Release 8 (early 2009) which included LTE, [5] by the 3GPP[6] it has been committed to ensuring it supported not only FDD but also TDD spectrum.

Within the globally assigned IMT spectrum bands for mobile broadband, there are significant spectrum resources suitable for TDD LTE deployment. Common 3GPP specifications for both FDD LTE and TD-LTE which ensures devices that support both the FDD and TDD interfaces on the same chipset.

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5 Long Term Evolution utilises orthogonal frequency-division multiple access (OFDMA) digital modulation.

6 The 3rd Generation Partnership Project (3GPP) is a collaboration between groups of telecommunications associations, to make a globally applicable third generation 3G mobile phone system specification within the scope of the IMT-2000 project of the ITU. 3GPP specifications are based on evolved GSM specifications. 3GPP standardization encompasses Radio, Core Network and Service architecture. See www.3gpp.org and for LTE specifically see www.3gpp.org/article/lte

Driven by China,[7] Japan (especially by Softbank), India and the United States (the latter especially as upgrade path from WiMAX[8]), assignments of the 2.6 GHz band followed option 3 given significant advantages of TDD. The TD-LTE variant in the 2.6 GHz was therefore harmonised globally as LTE Band 41. As well as adoption in those original supporting markets it has been widely adopted as summarised in section 3.4 of this Report.

One of the most important technical requirements towards 5G technology is to maximize spectrum efficiency. With the utilization of TDD technology providing significant advantages with respect to spectrum efficiency, network performance and capacity – TDD technology offers a viable evolution path from 4G towards 5G networks and services. As such, based on operator requests (including from Sprint in the US) the 3GPP 5G NR bands in sub-6GHz frequency range as defined in Release 15 include LTE Band 41 (b41).[9] In the new radio (NR) technology it will be known n41.

3.2 Benefits of the TDD option in today's 4G deployments

The use of the LTE Band 41 unpaired configuration gives significant benefits over employing the hybrid LTE Bands 7/38 configuration. TDD deployments based on this band plan facilitate the delivery of high quality wireless broadband services at lower cost per MB/GB for MNOs due to *inter alia*:

- Higher throughput performance based on massive MIMO antenna technology;
- Lower opex, due to more compact equipment size; and
- Lower capex including less need for filters, as no filtering is needed between FDD and TDD services.

This cost efficiency facilitates more affordable services, consequently aiding national broadband development goals – a benefit which is evident in the large-scale network deployment observed in countries which have adopted LTE Band 41. Further, as will be shown below, LTE Band 41 utilising TDD technology achieves a significantly higher spectral efficiency than spectrum utilising FDD technology. Hence is consistent with exemplar spectrum management regulatory objectives which apply in most jurisdictions.

Specific benefits of LTE Band 41 include:

(i) Advantages in dealing with traffic asymmetry;

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7 See for example, China, *Status updates on the 2300—2400 MHz band in ITU-R WP5D*. See DocumentAWF-9/INP-26, *9th Meeting of the APT Wireless Forum (AWF-9),* 13 September 2010

8 WiMAX and LTE share common characteristics, namely, a physical layer based on Orthogonal Frequency Division Multiplexing (OFDM), a flat IP architecture and use of multiple antenna system technique (MIMO) to achieve high data rates.

9 Refer to 3GPP TS 38.101-1 ver 15.0.0, 12-2017.

(ii) Provides more capacity and increased efficiency;

(iii) Comparable network coverage;

(iv) Avoids inter-band interference;

(v) Simplified network operation;

(vi) Key global roaming band;

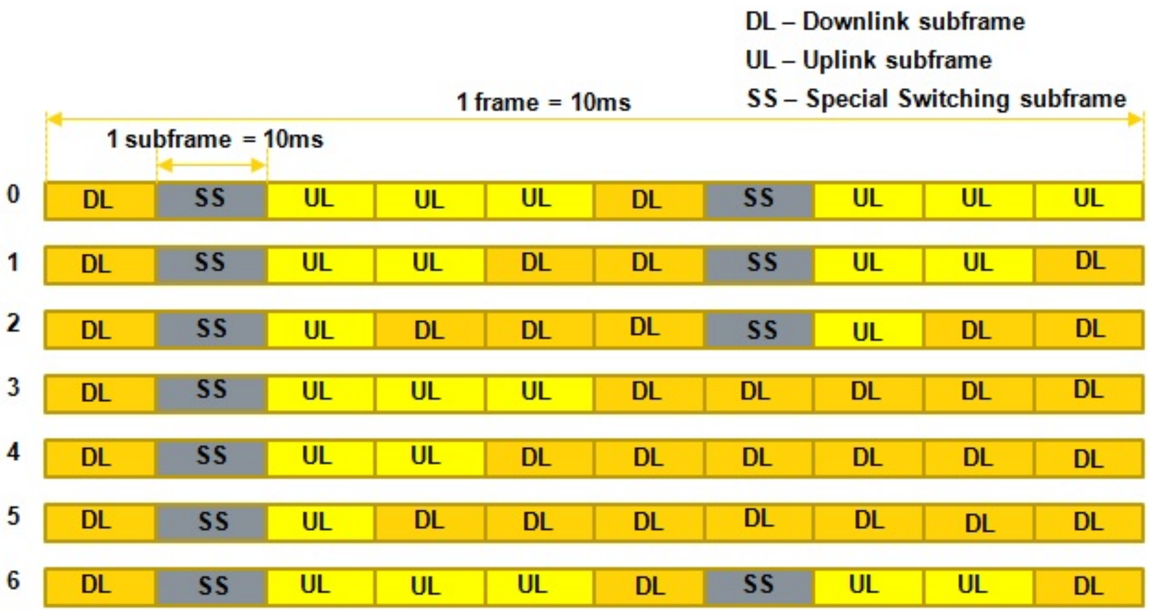
(vii) Typically lower spectrum cost for TDD spectrum; and

(viii) Easier to transition LTE Band 41 to 5G NR.

Advantages in dealing with traffic asymmetry

TDD enjoys a significant advantage over the FDD approach in dealing with traffic asymmetry, with TDD's adaptivity allowing for system characteristics to match the data traffic characteristics they are serving. This is because the uplink (UL)/ downlink (DL) adaptivity of TDD allows for the adjustment of the DL and UL resource ratios. A downlink-oriented configuration fits perfectly with the current and foreseeable user behaviour where streaming and data downloads use more downlink resources than uplink resources.[10]. Exhibit 3 below highlights the different TD-LTE Frame configuration options which are possible depending on traffic profile.

Exhibit 3: Different TD-LTE Frame Configuration Options depending on MNO traffic profile



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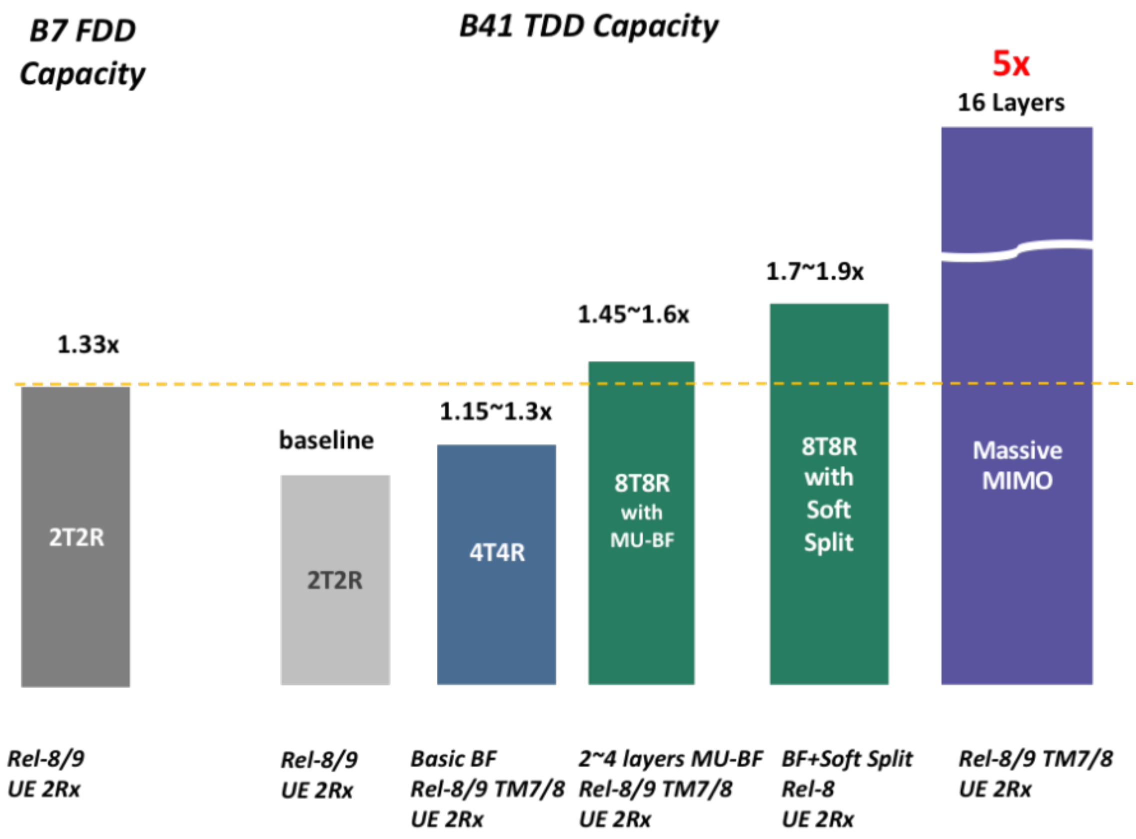
10 There is research trying to solve the issue of traffic asymmetry for the FDD networks. However, to achieve high asymmetry there needs to be significantly more spectrum for DL than for UL traffic. Such changes would require a time-consuming regulatory process and significant changes to network deployment. Refer to GTI, *5G Sub-6GHz Spectrum and Refarming White Paper*, 2018.

Provides more capacity and increased efficiency

LTE Band 41 provides much more capacity and increases efficiency compared with comparable FDD/TDD deployments in the 2.6 GHz spectrum band. FDD deployments in LTE Band 7 typically involveS high fragmentation (and hence small block sizes), 10MHz of guard bands to avoid interference, low bandwidth. It is complex to deploy massive MIMO to boost coverage in this configuration.

By way of comparison, LTE Band 41 permits large contiguous blocks, and there is no guard requirement (just synchronisation which is discussed in section 4.2 of this Report). The easy ability to deploy massive MIMO to boost coverage results in high capacity (eg 2.1Gbps@ 60MHz using B41 massive MIMO). This is summarized in Exhibit 4 below from Huawei.

Exhibit 4: LTE Band 41 provides much more capacity and efficiency



Source: Huawei Technologies, 2018

Comparable network coverage

Given the typical deployment in city and urban areas, deployments in 2.6 GHz using FDD or TDD technology are very similar.[11] In fact, equipment vendor studies and MNO operator experience with deploying LTE Band 41 with massive MIMO services is that it has comparable coverage to 1.8 GHz coverage using FDD (see Exhibit 5 below). Massive MIMO has been deployed commercially in 4G networks since 2017.

Importantly, such coverage can be down with a high level of performance. Massive-MIMO testing have been conducted by several operators including China Mobile, SoftBank and Vodafone to show the superb TDD network performance. For example:

1. *Capacity*: In a trial using 20MHz of TDD spectrum and 16 commercial smartphones, a peak throughput of 650Mbps was achieved when Massive-MIMO was used, which shows a 5 times improvement comparing to traditional 110Mbps baseline with 2T2R antenna configuration; and
2. *Coverage*: Using TDD Massive-MIMO in 2.6GHz gives a 0.5~1.5dB advantage over 1.8GHz 2T2R antenna configuration, and 7~8 dB gain compared to 2.6G FDD 2T2R.

Furthermore, the LTE Band 41 standard permits High Performance User Equipment (HPUE). HPUE is designed to improve the performance of TDD LTE Band 41 networks globally, by allowing higher power operation. This results in improved coverage and user experience at cell edge, meanwhile saving between 15 to 30 percent investment for MNOs.[12]

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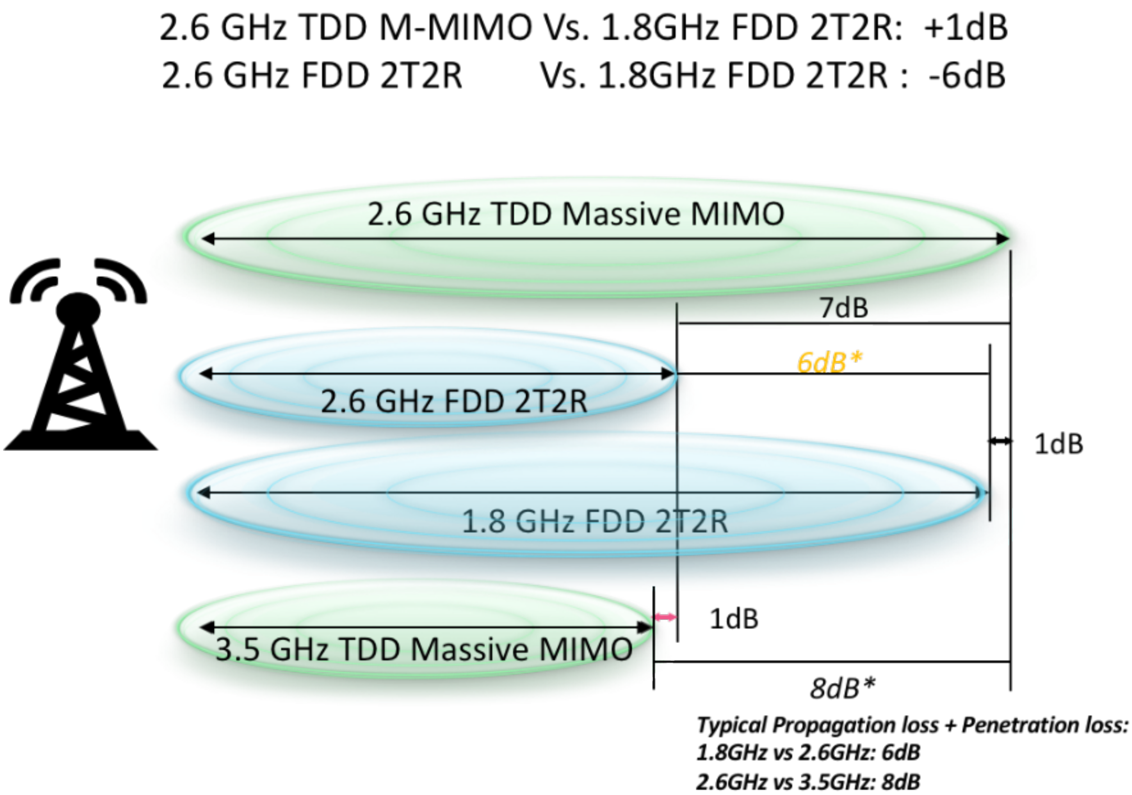
11 Approximately UL Cell range in dense urban environments is 0.27km with a coverage area of 0.14 km^2 and in urban environments a UL Cell range of 0.45 km with a coverage of 0.40 Km^2.

12 In accordance with the 3GPP Standard for LTE Band 41, devices with HPUE are permitted increases in their transmit output power from Power Class 3 (max transmit power of 23 dBm) to Power Class 2 (max transmit power of 26 dBm). HPUE is supported by *inter alia* China Mobile, US Sprint, and Softbank. HPUE devices and solutions for LTE Band 41 have been delivered to the market in an expedited manner, such that most phones now support HPUE, including the high end Android phones and the iPhone XS and XS Max from October 2018.

Exhibit 5: Coverage Comparisons for LTE Band 41 versus LTE Bands 7 and 3

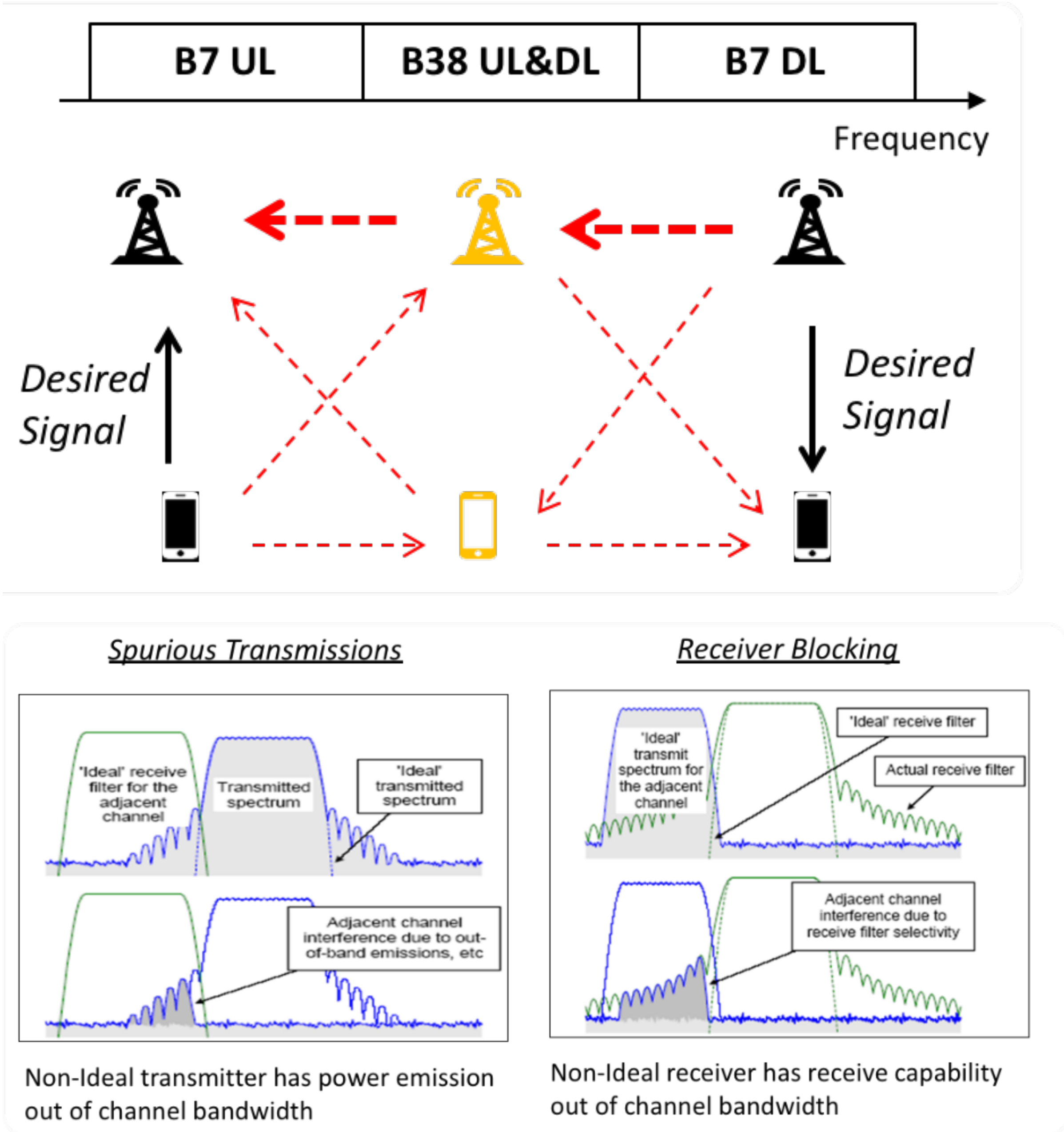


Avoids inter-band interference

Deploying LTE Band 41 which means that TDD technology is deployed across the entire 190 MHz spectrum band means that inter-band interference between LTD Band 7 (FDD) and LTE Band 38 (TDD). To avoid this inter-band interference, it is necessary to allocate two 5 MHz of guard band spectrum between the FDD and TDD spectrum allocation, utilize customised extra filters in the deployed equipment and practice, and mandated site space isolation etc.

These mitigations are needed in order to reduce spurious transmissions and receiver blocking as shown in Exhibit 6 below.

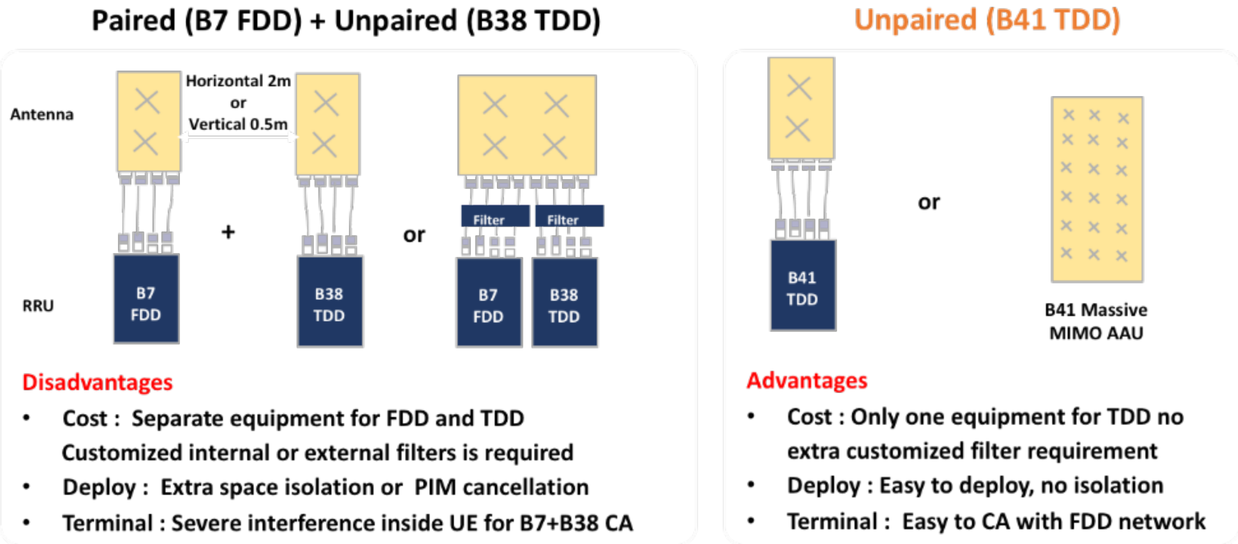
Exhibit 6: Possible harmful inter-band interference in hybrid LTE Band 7/38 deployments



Simplified network operation

Another benefit of LTE Band 41 deployment compared with the operation of hybrid LTE Band 7/38 configurations is that it provides simplified network operation with reduced network requirements, no customised filter requirements, space isolation issues etc. This is shown in Exhibit 7 below.

Exhibit 7: LTE Band 41 permits simplified network operation



Typically lower spectrum cost for TDD spectrum on a per MHz basis

Historically, unpaired spectrum which is used for TDD deployments has been priced lower on a per MHz basis in spectrum auctions and in spectrum valuations. While this may change in the future, and is highly dependent on particular country market dynamics and the total amount of IMT spectrum released to the market by the Government, the sale of 190 MHz of homogenous spectrum in LTE Band 41 (rather than 140 MHz of FDD and 40 MHz of TDD spectrum in the hybrid configuration) is likely to mean lower spectrum on a per MHz basis as the demand for MNOs can better be met. Importantly, it also means that additional IMT spectrum is made available to the market increases.

It should be noted that Governments may be net winners from the process in a revenue sense. This is because if all of the 190 MHz of LTE Band 41 is sold and there is not a pricing differential between the FDD and TDD spectrum nor are guard bands needed (which means that 10 MHz of the sellable spectrum is lost), total revenues to the Government may be higher than under other models.

Key global roaming band

Since the 2.3, 2.6 and 3.5 GHz bands for LTE-TDD have been deployed in many of the world's most populous countries, LTE-TDD has become a key global roaming technology band. This advantage stems from the historical development of TDD spectrum as the industry have worked to align underused spectrum bands for TDD.[13]

[13] ABI Research, *LTE-TDD Proves a Game-Changer for Carriers*, 2013. It expects a large amount of the TDD spectrum that was allocated for WiMAX to be used for LTE-TDD either by those operators or to be relicensed after those licenses have expired.

Easier to transition networks from LTE Band 41 to 5G NR

Use of TDD in the 2.6 GHz band offers the following benefits for 5G transition, namely:

- ***Accurate Beamforming*.** Due to uplink and downlink channel reciprocity (ensured by the fact that the same portion of spectrum is used in both link directions), TDD technology has unique coordination abilities which are used in a number of technical areas, including Beamforming. Beamforming improves the system performance by utilising channel state information to achieve transmit-array gain. FDD requires a very high signal overhead to obtain DL channel state information at the eNode B, thus making it less efficient when implementing Beamforming.

- ***Advanced antenna solutions***. Advanced antenna solutions, like Massive MIMO and Distributed MIMO, utilise TDD's uplink and downlink channel reciprocity to improve performance and capacity. Massive MIMO technology will unleash the powerful capability of the 5G network by taking the advantage of wide bandwidth when available, allowing for the flexible and accurate control of cell coverage radius. 4x4 downlink MIMO, particularly at frequencies above 2.5 GHz will be mandatory.[14] The vertical plan improves coverage for tall buildings, while the horizontal plane enhances coverage at near points and far points horizontally, enhancing cell capacity and user experience.[15] While, FDD can in principle employ Massive-MIMO it is likely it will require 20 percent more transmission overhead and modification to the legacy specifications. In contrast, TDD offers backward compatibility and channel reciprocity, meaning a smoother evolution to 5G.[16] LTE Band 41's spectral efficiency of approximately 48 bits/Hz greatly exceeds the 5G requirement of 30 bits/Hz and is almost 3.5 times the spectral efficiency of 14 bits/Hz for LTE Band 7.

- ***Smaller Equipment Size*.** In particular frequencies, the TDD antenna size is 50 percent smaller than the FDD antenna size. This implies easy deployment, and lower opex will be saved. It may also have advantages in networks where tower space is at a premium;

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14 Skyworks, *White Paper: 5G New Radio Solutions: Revolutionary Applications Here Sooner Than You Think,* 2018

15 www.telecomreview.com/index.php/articles/reports-and-coverage/2528-abundant-spectrum-resource-is-key-to-5g-experience

16 GTI, *5G Sub-6GHz Spectrum and Refarming White Paper*, 2018.

- ***Unpaired TDD bands can be made available more easily than paired bands.*** High performing mobile networks require wide channel bandwidths. From a spectrum management perspective, there are challenges making sufficient spectrum and wide channels available. Currently, spectrum bands between 1800MHz to 5GHz, where most of the harmonised mobile bands are TDD ones, are the best candidates for obtaining the wide channels of up to 100 MHz which are optimal in a 5G context . Unpaired spectrum bands are generally easier to make available than paired bands simply because re-farming of one band is easier than re-farming two equally wide bands. This benefit is becoming increasingly important, with re-farming of spectrum the main sourced of new mobile spectrum.[17]

In the context of ongoing IMT bandwidth scarcity, these developments provide compelling reasons to consider a careful cost-benefit evaluation of making new spectrum in the 2.6 GHz band using the most efficient configurations. This is particularly the case if the optimal configurations in the current context (ie LTE Band 41) also decrease the cost and time taken to move to new and better technologies.

3.3 Faster speeds - Carrier Aggregation Options with LTE Band 41

Given Asian markets already have LTE services deployed in a range of IMT bands including 700, 900, 1800 (most typical), 2100, and 2300 MHz another key benefit of deploying LTE Band 41 services is an increase in speed or bandwidth which can be offered to consumers. The increase in bandwidth is achieved by utilizing LTE carrier aggregation/channel aggregation ('CA') which combines multiple LTE carriers to increase bandwidth and achieve higher data rates of LTE-Advanced ('LTE-A')[18] and LTE-A Pro.[19]

LTE supports flexible usage of bandwidths including 5 MHz, 15 MHz, and 20 MHz standardised by 3GPP. These are called component carriers ('CC') and the current standards allow for a maximum of five CCs to be aggregated.[20] Therefore, maximum bandwidth that can be achieved is 100 MHz. CA with LTE Band 41 is already available in 2, 3 and 4 inter bands configurations with all of the other common IMT spectrum bands (see Exhibit 8). Such additional bandwidth provides more flexibility to MNOs and will significantly improve the quality of service offered to consumers.

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17 GTI, *5G Sub-6GHz Spectrum and Refarming White Paper*, 2018.

18 See www.3gpp.org/technologies/keywords-acronyms/97-lte-advanced

19 LTE-Advanced Pro (LTE-A Pro) is be used for specifications defined under 3GPP's Release 13 (R13) and Release 14 (R14). See www.3gpp.org/specifications/releases

20 See www.3gpp.org/technologies/keywords-acronyms/101-carrier-aggregation-explained for full CA configurations.

Exhibit 8: Selected Common IMT Bands usable in CA with LTE Band 41

Configuration	Bands	Max aggregated bandwidth [MHz]	3GPP Release
	Carrier Aggregation inter band (2 bands)		
1A-41A/ A(1)/C/D	TD2500 (b41) & 2100 MHz (b1)	40	3GPP R12.6 & R15.3
3A, C - 41A/A(1)/C/D	TD2500 (b41) & 1800 MHz (b3)	40, 60, 80, 100	3GPP R13.2, R14.0, R14.2 & R14.4
5A-41A	TD2500 (b41) & 850 MHz (b5)	30	3GPP R14.3
8A-B -41A	TD2500 (b41) & 900 MHz (b8)	30, 40, 50, 70	3GPP R13.0, R14.0, R14.1 & 14.2
26A-41A/C	TD2500 (b41) & 850+ MHz (b26)	35, 55	3GPP12.6
28A-41A	TD2500 (b41) & APT700 (b28)	30, 40, 50	3GPP R13.2 & 14.2
40A-41A	TD2500 (b41) & 2300 MHz (b40)	40	3GPP R14.1
41A-D-42A/C/D	TD2500 (b41) & 3500 MHz (b42)	60, 80, 100	3GPP R12.5, 13.4, & 14.0
41A/C/D – 48A/C/D	TD2500 (b41) & TD unlicensed	40, 60, 80, 100	3GPP R15.3
	Carrier Aggregation inter band (3 bands)		
1A-3A-41A/C/D	TD2500 (b41) & 2100 MHz (b1) & 1800 MHz (b3)	60, 80, 100	3GPP R14.0, R15.3
1A-5A-41A	TD2500 (b41) & 2100 MHz (b1) & 850 MHz (b7)	50	3GPP R14.4
1A-41A/C-42A/C	TD2500 (b41) & 2100 MHz (b1) & 3500 MHz (b42)	60, 80, 100	3GPP R14.0
3A-5A-41A	TD2500 (b41) & 1800 MHz (b3) & 850+ MHz (b5)	50	3GPP R14.1
3A-28A-41A/C	TD2500 (b41) & 1800 MHz (b3) & APT700 (b28)	60	3GPP R14.2, 14.3
5A-40A-41A	TD2500 (b41) & 850 MHz (b5) & 2300 MHz (b40)	50	3GPP R14.3
8A-28A-41A	TD2500 (b41) & 900 MHz (b8) & APT700 (b28)	50	3GPP R15.0
	Carrier Aggregation inter band (4 bands)		
1A-3A-5A-41A	TD2500 (b41) & 2100 MHz (b1) & 1800 MHz (b3) & 850 MHz (b5)	70	3GPP R14.4

Source: http://niviuk.free.fr/lte_ca_band.php E-UTRA CA Configurations 36.101 (Rel 15 June 2018)

Furthermore, LTE Band 41 can be deployed as CA inter-band where the downlink is non-contiguous (up to 5 carriers are permitted) with up to 100 MHz in total bandwidth[21] or contiguous (up to 5 carriers are permitted) with up to 100 MHz in total bandwidth.[22]

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[21] Refer to 3GPP Releases 11.5, 12.4, 12.5, 13.2, 14.3 and 15.1.

[22] Refer to 3GPP Releases 11.0, 12.4, 13.0, 14.3 and 15.0.

3.4 Growing number LTE Band 41 deployments in Asia and globally

There are a growing number of LTE Band 41 deployments in Asia and globally. The GSA reports on the global use of spectrum frequencies used for LTE as at August 2018.[23] Operators have now 25 commercially launched networks which utilise the 2.6 GHz spectrum band in the LTE Band 41 configuration in over 13 countries, as shown in Exhibit 9. Therefore, countries with a combined population of over 3.5 billion people have therefore allocated frequency spectrum which utilises TDD technology in LTE Band 41.

Exhibit 9: Global LTE Band 41 deployments

	Country	Operator	TDD Band
1	Angola	Net One	Band 41
2	Cambodia	Kingtel	Band 41
3	Cameroon	MTN	Band 41
4	Canada	Sasktel	Band 41
5	China	China Mobile	Band 39/40/41
6	China	China Telecom	Band 40/41
7	China	China Unicom	Band 39/40/41
8	Ghana	NITA	Band 41
9	Iraq	Tishknet	Band 41
10	India	BSNL	Band 41
11	India	Idea Cellular	Band 41
12	India	Vodafone	Band 41
13	Japan	Softbank	Band 41
14	Japan	UQ Communications	Band 41
15	Madagascar	Blueline	Band 41
16	Malawi	TNM	Band 41
17	Philippines	Smart	Band 41
18	Philippines	Globe	Band 41
19	Trinidad & Tobago	TSTT	Band 41
20	Uganda	MTN	Band 41
21	USA	Redzone Wireless	Band 41
22	USA	Rise Broadband	Band 41
23	USA	Speedconnect	Band 41
24	USA	Sprint	Band 41

Source: GSA LTE TDD (TD-LTE) Global Status, 2017 with updated information from WPC research

[23] https://gsacom.com/paper/5g-evolution-lte-global-market-status/

3.5 LTE Band 41 compatible devices are widely available and affordable

The GSA and other industry studies emphasise that there is a growing maturity of the ecosystem in LTE Band 41. LTE Band 41 is currently the 3rd most popular of all LTE TDD devices and 11th out of all LTE devices, with at least 2,749 compatible devices.[24] New devices from leading manufacturers such as Huawei, Apple (including the Apple Watch),[25] Samsung, as well as manufacturers of lower cost devices, are compatible with and support the uptake of LTE Band 41.

It should be noted that these totals and rankings of LTE devices are based on data which refer to accumulated user devices. The user device ecosystem for LTE Band 7 started around 2008/09, whereas the commercialisation of LTE Band 41 started around 2012/13. Specifically, Qualcomm announced that its line of multi-mode LTE chipsets will support for 3GPP's LTE Band 41 (b41) radio frequency in May 2012.[26] Taking this into account, this ranking also reflects the LTE Band 41's immense growth in popularity and uptake amongst device manufacturers since its introduction, especially in Asia. All or almost all devices sold today and for the past 2-3 years have supported the TDD band.

3.6 Case Studies

SoftBank in Japan

SoftBank, Japan's third-largest operator, commercially launched LTE-TDD in November 2011 through its Wireless City Planning subsidiary, deploying its service in LTE Band 41. The company used its 30MHz of available bandwidth to gain a competitive advantage against more spectrally challenged competitors in the market, building out an extremely dense network of approximately 160,000 small cells initially.

According to SoftBank CEO Masayoshi Son, the operator chose LTE TDD for two unique advantages – asymmetric uplink/downlink and abundant spectrum resources. Son believes that LTE TDD can fully meet the needs of mobile internet service, and enhance user experience for the foreseeable future. Notably, thanks to the expanded terminal and network coverage, SoftBank attracted 260,000 LTE customers in its first nine months of deployment.[27]

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24 GSA, *LTE Ecosystem Report*, August 2018

25 For example, see www.apple.com/au/watch/cellular/

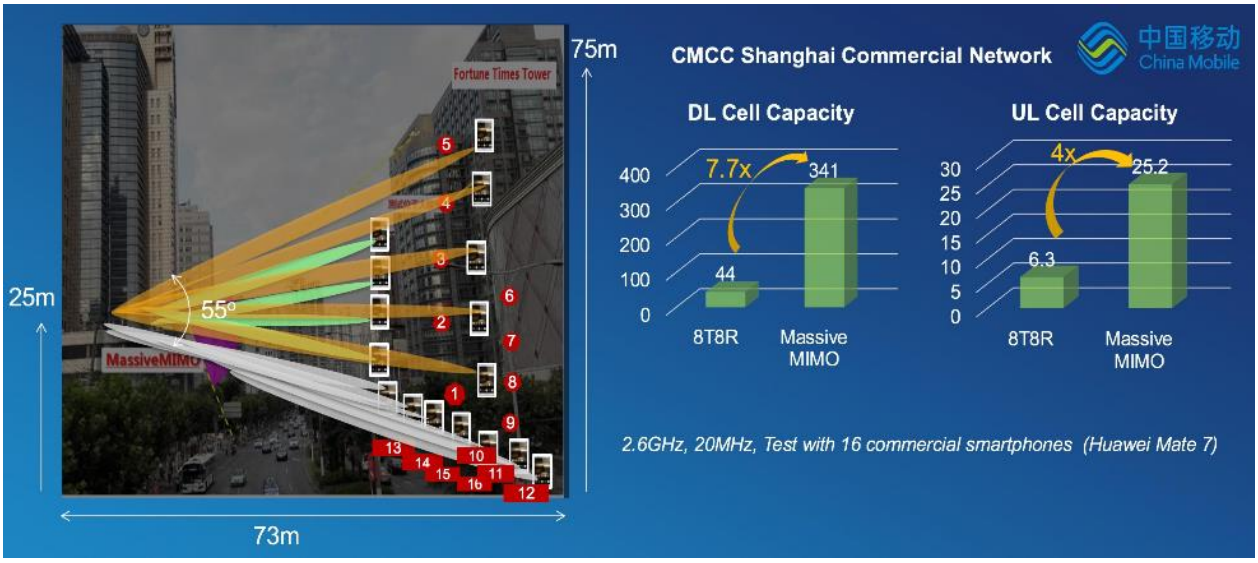
26 See www.qualcomm.com/news/releases/2012/05/08/clearwire-expands-lte-choices-north-america

27 www.huawei.com/en/about-huawei/publications/winwin-magazine/14/HW_196683

China Mobile in China

In China, China Mobile utilizing 20 MHz of TDD 2.6 GHz spectrum used massive MIMO for 3D beamforming for capacity and coverage as shown in Exhibit 9 below. This has resulted in 7.7x increase in download cell capacity and 4.0x upload cell capacity.

Exhibit 10:Testing in China with Massive MIMO



Source: Huawei Technologies, 2018

Globe Telecom in the Philippines

In July 2017, Globe Telecom commenced the commercial deployment of massive MIMO technology to improve the mobile connectivity experience in dense urban areas of the Philippines.[28] In the Philippines uses LTE Band 41.

The commercial deployment follows initial testing of the technology in the Makati financial district of Metro Manila. The testing demonstrated the ability of the technology to improve capacity up to 6 times compared to a regular site. Globe's initial rollout will cover 150 cell sites, mostly in Southern Luzon and Northern Luzon. In the first six months of 2018, Globe Telecom rolled out an additional 1,752 LTE sites operating on the 700MHz and 2.6 GHz spectrum bands.

The use of massive MIMO technology is an important component of Globe's goal to stay ahead of the demand curve for data capacity in densely populated and high-foot traffic areas. In July 2017, Globe became the first operator in the world to activate massive MIMO using two-carrier aggregation. This deployment makes use of Globe's 2.6-GHz TDD spectrum holdings.

[28] www.telecomasia.net/content/globe-commences-massive-mimo-rollout

Globe Telecom has seen as sharp increase in data traffic flowing across its networks, due in no small part to the company's focus on LTE rollout using massive MIMO technology. In the first half of 2018, traffic on Globe's networks rose from 280 Petabytes to 390 Petabytes – a near 40 per cent jump. The customer's use of data is evolving and an aggressive network upgrade will enable Globe to satisfy customer demand for bandwidth, which they forecast is likely to increase further moving forward.

US Sprint in the United States

Sprint owns a vast amount of spectrum for LTE thanks to the 2.6 GHz spectrum holdings it acquired from Clearwire in 2013.

In December 2017, Sprint announced that its 2.6 GHz spectrum band is included in the Non-Standalone 3GPP 5G NR specification (initial part of Release 15) ratified at the 3GPP TSG RAN plenary meeting in Lisbon.[29] With more than 160 MHz of 2.5 GHz spectrum available in the top 100 US (urban) markets, Sprint has the largest nationwide block of sub-6 GHz 5G spectrum available for wide-scale use in the US.

Sprint's priority is mobile 5G, and the company is working with Qualcomm and SoftBank to develop technologies for wide-scale 5G deployment. Sprint plans to provide commercial services and devices in late 2019. In addition, Sprint is working with its RAN (Radio Access Network) suppliers for end-to-end availability of 5G NR in Sprint's 2.6 GHz (n41) spectrum.

Sprint's initial path to market for 5G will be through the deployment of 2.6 GHz Massive MIMO radios slated for commercial use in 2018. These 64T64R (64 transmitters, 64 receivers) radios will be software-upgradable to 5G NR. In May 2018, it announced that it will deploy 128-radio massive MIMO equipment on its tri-band towers for 2.6 GHz spectrum using a 4G/5G split in nine US cities, namely Atlanta, Chicago, Dallas, Houston, Kansas City, Los Angeles, New York City. Phoenix, and Washington, DC.[30]

29 http://investors.sprint.com/news-and-events/press-releases/press-release-details/2017/Sprints-25-GHz-Spectrum-Included-in-Non-Standalone-3GPP-5G-NR-Specification/default.aspx

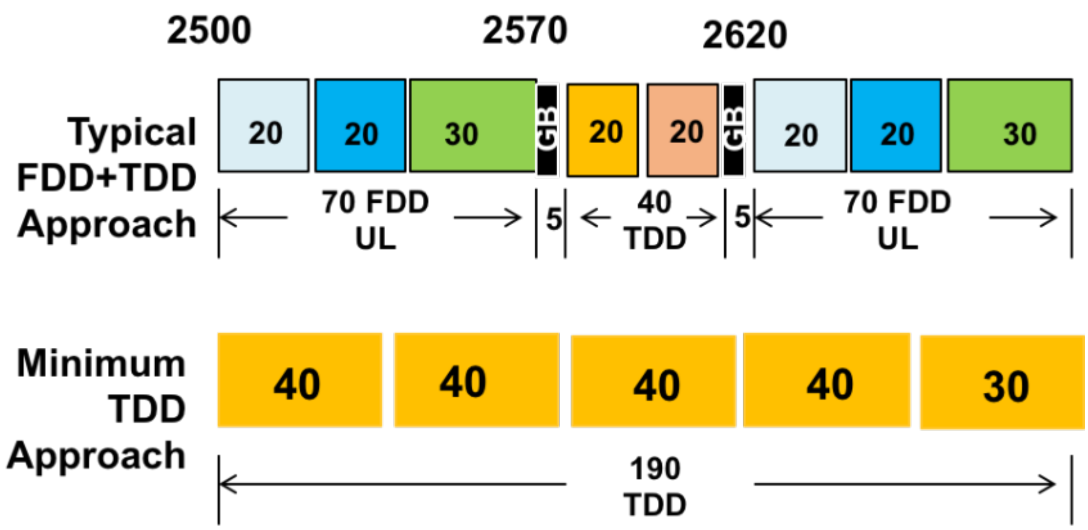
30 www.rcrwireless.com/20180516/5g/sprints-5g-strategy-massive-mimo-key-to-2-5-ghz-rollout-tag41

4 Optimal deployment of LTE Band 41 networks

4.1 2.6 GHz spectrum band release recommendation

In order to future proof and allow sufficient transmission capacity, the preferred block size for the 2.6GHz band is 60 or 70MHz, with the recommended minimum block size being 40MHz. An example of such a possible implementation is shown below in Exhibit 11. The allocation or spectrum auction of a single 190 MHz TDD block in the 2.6 GHz strongly supports sector competition by enabling the allocation of efficiently sized blocks to around 3 to 5 MNOs depending on the market.

Exhibit 11: Example of the possible division of 2.6 GHz



It should also be noted that LTE Band 41 is an ideal choice for countries who need more spectrum, especially for countries whose available 3.5 GHz (ie C-Band) spectrum for future 5G services may not be adequate and/or may take long time to refarm for IMT services. In such circumstances, while a number of vendors and indeed some country regulators such as EU[31] and New Zealand[32] support larger contiguous spectrum blocks of up 100 MHz for 5G, the 2.6 GHz band in its TDD configuration can support these larger optimal MNO allocations.

[31] See Draft, *ECC Report 287 on Guidance on the defragmentation of the frequency band 3400-3600 MHz*.

[32] See www.rsm.govt.nz/projects-auctions/current-projects/preparing-for-5g-in-new-zealand/technical-consultation/5g-spectrum-road-map-discussion-document.pdf

For example, in a 4 operator market the 2.6 GHz band would support three allocations of 50 MHz and one of 40 MHz; in a 3 operator market, the band can support two allocations of 60 MHz and one of 70 MHz. While not ideal for 5G, such allocations would be more than usable and consistent with the competition limits being set in some markets for early 5G spectrum.[33] Importantly, if the 2.3 GHz band was licensed or auctioned simultaneously with the 2.6 GHz band then each operator in a 3 operator market could be allocated almost 100 MHz of spectrum. This would improve integrated 4G+5G investment efficiency (by allowing say 40 MHz to be allocated for TDD LTE and 60 MHz for 5G).[34] Such factors should be considered by regulators in their spectrum allocation decisions.

4.2 Addressing TDD Synchronisation Issues

TDD synchronisation[35] is preferred in the scenario of multiple TDD operators in the same area and results in the more efficient use of the radio spectrum, and the efficient mitigation of base-to-base and mobile-to-mobile harmful interference in the TDD bands. Serious interference will occur if TDD networks of different operators in the same area or country are neither synchronized nor arranged given uplink and downlink time slot settings. For instance, if a transmitter of operator A is transmitting while a receiver of operator B is trying to obtain its own signal at the same time.[36] Additional frequency guard band or transmitter filter or other interference elimination solutions are therefore required.

Predefined TDD frame settings are therefore set among the operators. Basically, TDD base stations for all the operators in a market therefore transmit or receive in the very same time slot, so that no interference exists among equipment of different licensed operators. Technically this requirement results in following two requirements:

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[33] In the upcoming 3.5 GHz spectrum auction in Australia, the Australian Competition and Consumer Commission recommended that allocation limit of 45 MHz apply to a single MNO's aggregate holdings across the 3.4–3.7 GHz band in Sydney and Melbourne with an allocation limit of 60 MHz on the same spectrum range in other metropolitan and regional areas. See www.accc.gov.au/system/files/ACCC%20advice%20to%20Minister%20Fifield%20on%203.6%20GHz%20allocation%20limits.pdf

[34] The corollary of 5G being optimised for larger spectrum blocks is that Asian and global regulators need to support mechanisms for spectrum trading which would permit MNOs to trade and/or swap spectrum allocations with other MNOs to create larger contiguous spectrum blocks in *inter alia* the 2.3 and 2.6 GHz bands as well as future allocations in 3.5 GHz and other 5G bands.

[35] Synchronisation involves aligning the periods of time when different base stations transmit to user terminals (that is, the downlink (DL)) and receive transmissions from user terminals (that is, the uplink (UL)).

[36] In such circumstances, the receiver of operator B could have its transmission blocked or having its noise floor rise dramatically, due to the out-of-band emission of transmitter of operator A and non-ideal adjacent channel signal selection of receiver of operator B.

- Each operator has the same TDD frame starting point; and
- Each operator uses the same TDD uplink and downlink time slot setting. The agreed frame setting uses uniformed uplink and downlink time slot setting, while the special sub-frame is not required to be the same.[37]

The main benefit of such an approach is that it removes or at least minimises the need for guard bands or other restrictions to achieve coexistence between licensees.

Examples of recent awards of unpaired spectrum in four major Asian markets, highlight that coming to an agreement on synchronisation is relatively straightforward:

- In ***China***: Operators of TDD networks have synchronised in Band 40 (2.3 GHz) and Band 41 (2.6 GHz), both based on TD-LTE frame configuration 2 (3:1 downlink/uplink ratio);
- In ***Japan***: In relation to the recent award of Band 42 spectrum in Japan, the 3 licensees intend to synchronise based on TD-LTE frame configuration 2 (3:1 downlink/uplink ratio);
- In ***India***: Following the award of licences for Band 40 (2.3 GHz), the two licensees have, agreed on a common synchronisation pattern and roll out commenced shortly thereafter; and
- In ***Indonesia***: Following the recent spectrum auction of Band 40 (2.3 GHz) by the SDPPi,[38] where Telkomsel was successful, it and Smartfren have synchronised based on TD-LTE frame configuration 2. Indonesia MNOs have synchronisation agreements with TD-LTE operators in Malaysia and Singapore.

According to the synchronisation requirements in 3GPP TS.36.133, TD-LTE base station output carrier signal frequency accuracy should be less than 0.1 ppm, and the cell phase synchronization accuracy applied to the overlapping cells should be equal or less than 3 μs for the cell radius up to 3 km. Available techniques to meet these requirements include: GPS synchronization scheme, IEEE 1588v2 synchronization scheme suing Precision Time Protocol (PTP) [39] and air interface synchronization scheme.

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37 Refer to APT Report on *Network synchronization technologies in radio access networks for IMT TDD systems, No. APT/AWG/Rep-60*, Edition: March 2015.

38 Ditjen Sumber Daya dan Perangkat Pos dan Informatika (SDPPI). In English, the Directorate General of Resources and Equipment of Post and Information Technology of the Republic of Indonesia. Refer to www.postel.go.id

39 https://standards.ieee.org/standard/1588-2008.html

It should also be note that while guard bands are a possibility (albeit sub-optimal) in a 4G environment, testing and the investigations by equipment vendors and exemplar national regulators have found that synchronisation is mandatory in the context of 5G systems.[40] Given this, it is preferable if synchronisation is adopted in relation to LTE Band 41.

In conclusion, the industry experience demonstrates that where there is a real willingness to use the spectrum, full synchronisation between operators is a key enabler in the successful deployment of IMT networks in unpaired spectrum.

4.3 Possible transition from the hybrid 2.6 GHz band plan (LTE Bands 7/38) to LTE Band 41

While there are currently no reported examples of country markets which have transitioned from the FDD/TDD hybrid band plan (namely LTE Bands 7/38) to the LTE only Band 41 band plan, there are countries in Africa, the Middle East and Europe which are engaging with industry stakeholders including MNOs about the possibility of doing so.

In Asia, especially for those countries for which it is challenging to secure C-Band spectrum (ie the 3.5 GHz) for future 5G services given current assignments and use of such spectrum by satellite services it is likely that serious consideration will be given to the transition to LTE Band 41. One example, could be Malaysia in respect of which the current 2.6 GHz licences issued in the FDD/TDD configuration expire in 2019. South Africa is another possibility even though the 3.5 GHz spectrum is available.

Certainly, it is compelling for countries that have either:

(i) not yet allocated spectrum in the 2.6 GHz Band (eg Indonesia, Thailand, Sri Lanka and Vietnam); or

(ii) where they have so, have only allocated LTE Band 38 spectrum (eg Myanmar),[41]

to adopt the LTE Band 41 band plan given the advantages which have been outlined in this Report.

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[40] ACMA, 3*.4 GHz and 3.6 GHz band spectrum licence technical framework: Consultation paper*, May 2018. See www.acma.gov.au/theACMA/3_6-ghz-band-legislative-instruments-consultation

[41] LTE Band 38 is a subset of LTE Band 41.

The transition from the hybrid band solution assuming that mid-band gap is either vacant or allocated in accordance with LTE Band 38 would require consultation and planning with affected spectrum licensees and would be optimally be done at the end of a spectrum licence period, where the 2.6 GHz spectrum band was re-auctioned in accordance with LTE Band 41. It is more complex process if a preference to convert from the hybrid band was agreed during the licence period or as part of any spectrum licence extension.

It should also be noted that in April 2018, the United States' FCC released a fact sheet: Transforming the 2.5GHz Band (the 2.6 GHz band is known as the 2.5 GHz band in the US). The FCC proposed to provide greater flexibility to current EBS licensees as well as provide new opportunities for educational entities, rural Tribal Nations, and commercial entities to obtain unused 2.5 GHz spectrum to facilitate improved access to next generation wireless broadband, including 5G, for both educational and commercial uses.[42]

Currently, Significant portions of the 2.5 GHz band currently lie fallow across approximately one- half of the United States, primarily in rural areas. Access to this spectrum has been strictly limited since 1995, and current licensees are subject to out-dated regulations. In May 2018, FCC announced plans to auction the 2.5 GHz band (2496– 2690 MHz) for 5G.

The FCC adopted a Notice of Proposed Rulemaking (NPRM) to consider updating the framework for licensing Educational Broadband Service (EBS) spectrum in the 2496MHz-2690MHz (2.5GHz) band. The FCC notes that this band constitutes the single largest band of contiguous spectrum below 3GHz, and as such, is prime spectrum for next-generation mobile services such as 5G.

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42 www.fcc.gov/document/transforming-25-ghz-band

5 The economic benefits arising from allocating 2.6 GHz spectrum and adopting LTE Band 41

5.1 Spectrum demand, cities and economic growth

Spectrum congestion means constrained economic growth

Given the ongoing high demand for mobile spectrum throughout Asia and globally, recent mobile technology developments and the inevitability of future upgrades to new standards (in particular 5G) it is timely to consider the economic benefits of improved approaches the utilisation of spectrum currently allocated to mobile use.

Of particular economic importance is the availability of high capacity, data rich mobile services in cities. Global cities are increasingly the driving force of national competitiveness and economic growth and mobile data services are a critical input to the functioning of these modern cities. This is especially the case in Asia. The important of addressing spectrum in an urban context was the subject of the GSMA's February 2018 report entitled *Delivering the Digital Revolution: Will mobile infrastructure keep up with rising demand?*[43]

Multiple economic studies have pointed to the positive impact on consumer welfare and economic growth from increased availability and quality of telecommunications services.

Cities and economic growth

Why focus on cities? A ground breaking 2012 report[44] from the McKinsey Global Institute research indicated that per capital GDP rises with urbanisation levels. Cities provide significant economies of scale in infrastructure and drive national innovation and competitions. The cities above are the economic engine rooms of developing world. The quality of their infrastructure and services and the efficiency with which they operate are critical national economic prospects.

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[43] See www.gsma.com/publicpolicy/wp-content/uploads/2018/02/GSMA_DigitalTransformation_Delivering-the-Digital-Revolution.pdf

[44] *Urban world: Cities and the rise of the consuming class*, Richard Dobbs, Jaana Remes, James Manyika, Charles Roxburgh, Sven Smit, and Fabian Schaer. www.mckinsey.com/featured-insights/urbanization/urban-world-cities-and-the-rise-of-the-consuming-class

The flip side of this positive scenario is that mobile bandwidth congestion is bad for economic development. Generally speaking, Asian cities and those in emerging markets need more spectrum for mobile services and the sooner the better.

Timing is important not just because the need for better services is urgent in terms of the constraints which congestion places on consumers and business users, but also because the benefits of greater spectrum availability compound over time. In essence, economic growth off a larger base delivers greater absolute benefits indefinitely into the future.

Getting to the app economy sooner

App economy disruption of traditional business models has become perhaps the dominant recent theme in the ongoing evolution of information and communications technologies.[45] But in in Asia, even more than in more developed economies with their developed fixed network infrastructures, spectrum is the lifeblood of the app economy. Where spectrum is congested, where data speeds are low, where data caps are limiting use and where service is unreliable, consumers will be less likely to integrate data intensive apps into their daily lives and innovators will be less able to build and market apps that improve peoples' lives, enhance efficiency and productivity, and contribute to economic growth.

Spectrum is available that would solve many of these problems. And there is a lot of it in the 2.6 GHz band. As much as 190MHz of new spectrum could be made available in most of these cities in this band. For example, making the 2.6 GHz spectrum band available would represent around a 50 per cent increase in total IMT spectrum allocated in Sri Lanka and Thailand,[46] 35 percent in Indonesia and 25 per cent in Vietnam. Furthermore, this spectrum could be made available quickly and are relatively low capital costs. Depending on the market spectrum in the 2.3 GHz, 3.4-3.7 GHz and mmWave bands could also be allocated and significantly increases the total IMT spectrum allocated in a market.

Spectrum below 1 GHz such as the 700 MHz band will be critical in providing coverage in less densely populated areas and in providing fall-back access in urban areas given its better in building performance compared with higher frequencies.[47]

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45 *ITU discussion paper, The Race for Scale: Market Power, Regulation and the App Economy*, GSR-16, Sharm el Sheikh, Egypt, May 2016.

46 As at September 2018, Sri Lanka has 340 MHz of IMT spectrum allocated to mobile use or 415 MHz in total IMT spectrum allocated if fixed only 2.3 GHz spectrum allocations are included. Thailand has 380 MHz of total IMT spectrum allocated but it has plans to release 380 MHz more IMT spectrum (including parts of the 2.6 GHz band) by 2020. See https://disruptive.asia/ericsson-demos-5g-nbtc-spectrum/

47 GSMA, *Securing the digital dividend across the entire ASEAN, A report on the status of the implementation of the APT700 for the ATRC*, August 2018

It does not have, however, sufficient carrying capacity to meet high levels of future demand in urban areas.

Whatever spectrum is used, it is critical to acknowledge its fundamental scarcity and utilise it as efficiently as possible and to anticipate, as far as possible, future developments in technology and standards so that upgrade paths can be a low cost and rapid as possible.

Using spectrum efficiently and future-proofing

Spectrum in the 2.6 GHz band is generally underutilised in Asia in contrast with much of the rest of the world. Although there is a large amount of spectrum in the 2.6 GHz band, the potential for growth in consumer demand for mobile services could quickly make use of this additional capacity. Therefore, it is critical that spectrum in this spectrum band be configured as efficiently as possible.

There are significant economic benefits associated with assigning spectrum in the 2.6 GHz band using the unpaired LTE Band 41 configuration option. These benefits are associated with more efficient spectrum use, lower capital and operational costs, and its ability to offer the cost-effective upgrade path to 5G in the future. These benefits translate directly into significant economic benefits which are discussed in the next section.

5.2 Sources of economic benefits from more spectrum and better spectrum utilisation

The source of all economic benefits is improvements in efficiency or improvements in the way that resources are changed outputs – products and services. Typically, improvements in technology lead to more efficient more productive production processes which, in turn, enables products and services to be offered to consumers at a lower price, or enables better quality or entirely new products to be offered.

Productivity improvements occur within specific industries (microeconomic benefits) and, these improvements when aggregated across all industries, lead to national economies that are more competitive and experience more rapid economic growth leading to higher living standards for their citizens (macroeconomic benefits). For the allocation of spectrum in the 2.6 GHz band as discussed above the economic benefits which accrue can be characterised as follows:

1. **Economic benefits of additional spectrum:** from an economic perspective, more spectrum is better. The large block of 190 MHz spectrum will enable significantly enhanced mobile communications and data experiences for consumers and business users. This block is maximised if the need for guard bands is avoided in the adoption of LTE Band 41 enables the use of advanced technologies such as MIMO across the entire band which enables much greater throughput per unit of spectrum. Improved communications efficiencies across multiple industries would lead to significant productivity benefits and overall improvements in national competitiveness and therefore faster economic growth.

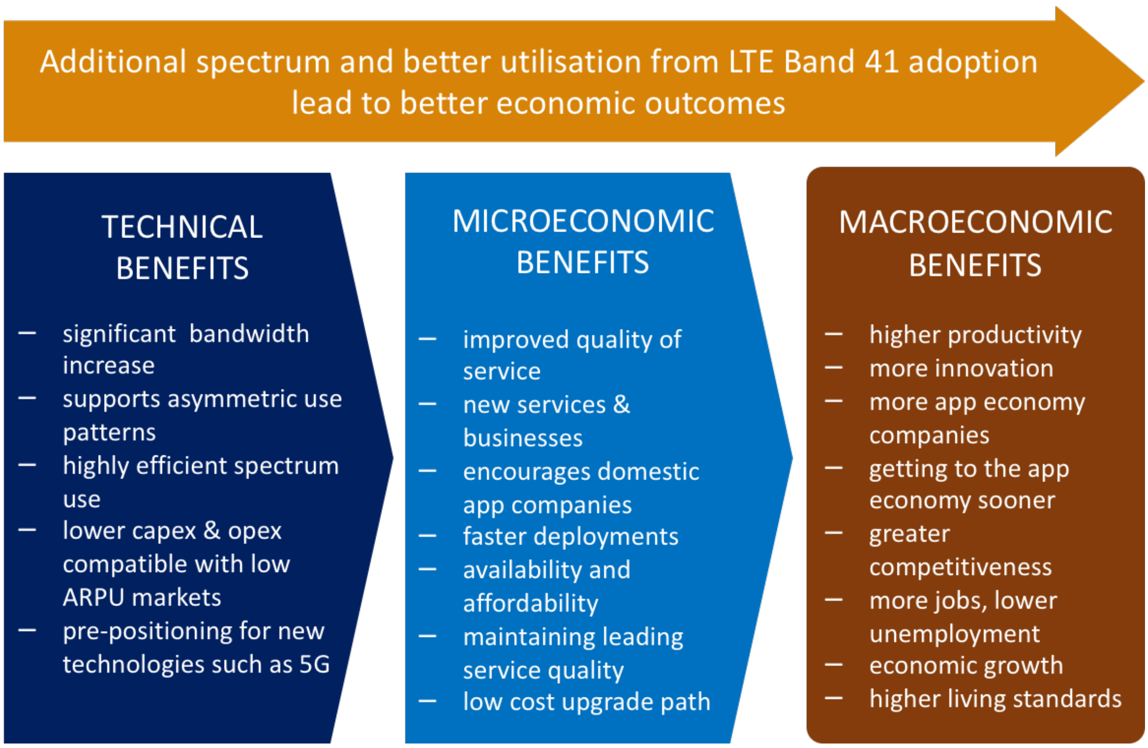
2. **Optimising spectrum for the app economy:** it is critical that any new spectrum is optimised for the asymmetric use patterns of modern data rich mobile services that are characteristic of the app economy. It is critical that spectrum configuration be aligned with data-centric use patterns because this will encourage the development and deployment of productivity-enhancing app-based services that have delivered significant business and consumer benefits in other jurisdictions.

3. **Minimising future upgrade costs:** mobile technologies and standards will continue to evolve and deploying additional spectrum as described above will minimise the cost and time taken to move to take advantage of such new developments. This is a particularly critical factor in the context of some Asian jurisdictions which have relatively low monthly ARPUs, compared with developed country markets. Low monthly ARPUs mean that MNOs are challenged to justify investment expenditures to upgrade to new technologies and standards, such as 5G especially where such technologies require a material increase in capital intensity to smaller cell sizes etc. Anything that can be done to optimise future upgrade paths – such as the adoption of TDD technologies in the 2.6 GHz band - will make it more likely that consumers and businesses enjoy the benefits of new technologies like 5G sooner.

   Where technical prohibit or unduly delay the deployment of such technologies (such as may happen given the difficulties in securing 3.5 GHz spectrum in parts of Asia for early 5G deployment, it is even more critical to find workable alternatives such as the use of the 2.6 GHz band.

These economic benefits are summarised in Exhibit 12 below.

Exhibit 12: Summary of the economic benefits of deploying LTE Band 41



6 Conclusions and Recommendations

In conclusion, there are compelling reasons for Government and industry regulators to allocate additional IMT spectrum including the 700 MHz, 2.3 GHz, 2.6 GHz and 3.5 GHz, where available to 4G and future 5G mobile usage in most markets as soon as practicable.

In respect of the 2.6 GHz spectrum band, given the need for increased bandwidth supply in Asian and global markets and given rapidly increasing video consumption by mobile users, this spectrum band should be available for use as soon as practicable. It is, however, not enough to just make it available – ***optimally it should be made available for use by endorsing the TDD configuration of LTE Band 41*** instead of the alternative hybrid FDD/TDD configuration of LTE Bands 7/38.

Adopting TDD for the entire 2.6 GHz band has a range of significant benefits *inter alia*:

- The shift from FDD to TDD technologies will enable better matching of current upload and download use patterns which are likely to become more asymmetric over time. Optimising spectrum for use has significant economic benefits;
- TDD supports the use of new techniques such as MIMO technologies which offer around 5 times better spectrum utilisation. Spectral efficiency should be at the core of spectrum management decisions by regulators and Governments in relation to IMT spectrum;
- Elimination of the need for 10 MHz of guard bands – this is not insignificant (approximately 5 percent of the band) in the context of ongoing IMT spectrum scarcity especially in spectrum below 3 GHz;
- The LTE Band 41 network deployment will result in lower per MB/GB costs for MNOs and hence makes compelling commercial sense for MNOs in the context of relatively low Asian monthly ARPUs. Such lower costs will allow more affordable retail tariffs which is a regional policy objective;
- As historically unpaired/TDD spectrum has been priced below paired FDD spectrum on a per MHz basis in spectrum auctions, there are likely to be benefits for industry for the adoption of LTE Band 41. There are also benefits for regulators and Government in allocating/auctioning a homogenous block of 190 MHz spectrum rather than attempting to sell hybrid spectrum allocations. Importantly, larger block sizes of up to 100 MHz are (i) optimal in a 5G context and (ii) improve integrated 4G+5G investment efficiency (by allowing say 40 MHz of spectrum to be allocated for TDD LTE and 60 MHz for 5G). Such factors should be considered by regulators in their allocation decisions;

- The allocation or spectrum auction of a single 190 MHz TDD block strongly supports sector competition by enabling the allocation of efficiently sized blocks to around 3 to 5 MNOs (for example, three lots at 50 MHz and one lot at 40 MHz or three allocations of 40 MHz to the MNOs in a market plus 70 MHz which can be contested in any auction). Such lot sizes, while not optimal (100 MHz is optimal for 5G), are more than sufficient to provide future 5G services in this band; and
- TDD configuration of the 2.6 GHz band enables transition to 5G at lower capital cost and therefore enables more Asian and global consumers to participate in the upcoming 5G revolution. They can also participate sooner.

The technical advantages of LTE Band 41 in the 2.6 GHz band, leads directly to a set of compelling economic benefits that are of particular value in emerging economies.

Mobile spectrum is the economic life-blood of both emerging and developed economies. It is a critical input for more efficient markets and for the business innovations associated with the App economy. The benefits of more mobile bandwidth begin at the level of individual industries and markets (the microeconomic level) as improvements in communications and data services flow through to greater productivity and the creation of new businesses. This creation of new jobs, new businesses and new sources of wealth will accumulate across industries and lead to better macroeconomic outcomes such as faster economic growth and job creation, lower unemployment and greater income per capita.

High quality mobile communications services which arise from deploying LTE Band 41 infrastructure particularly in cities and urban areas should be regarded as a form of national infrastructure without which economic development is likely to be highly constrained.

- END -

7 APPENDIX A: Glossary of Abbreviations

3GPP	3rd Generation Partnership Project (uniting 7 standardisation bodies)
4G	Fourth generation of broadband cellular network technology
5G	Fifth generation of cellular mobile communications
5G NR	5G New Radio. The global standard for a new OFDM-based air interface.
APT	Asia-Pacific Telecommunity
ASEAN	Association of South East Asian Nations
ARPU	Average Revenue Per User
CA	Carrier Aggregation
Capex	Capital expenditure
CEPT	European Conference of Postal and Telecommunications Administrations
dB	Decibel. It is a relative unit of measurement. commonly used for providing a reference for input and output levels.
DL	Downlink
EBS	Educational Broadcast Band formerly known as the Instructional Television Fixed Service (ITFS) as designated by the FCC in the USA in the 2.6 GHz band
FCC	Federal Communications Commission of the USA
FDD	Frequency Division Duplex
GB	Gigabyte
Gbps	Gigabites per second
GDP	Gross Domestic Product
GPS	Global Positioning System
GSMA	The GSM Association is industry body that represents the interests of MNOs worldwide
HPUE	High Performance User Equipment

IEEE	Institute of Electrical and Electronic Engineers
IMT	International Mobile Telecommunications
IoT	Internet of Things
ITU	International Telecommunications Union
ITU-RR	ITU Radio Regulations
LTE	Long Term Evolution
MB	Megabyte
Mbps	Megabits per second
MIMO	Multiple-input and multiple-output
mmWave	Millimetre Wave – for 5G currently focused on 24 to 28 GHz and other higher frequency bands
MNO	Mobile Network Operator
OFDM	Orthogonal Frequency Division Multiplexing
Opex	Operating expenditure
TDD	Time Division Duplex
UE	User Equipment
UL	Uplink
WARC	World Administrative Radio Conference (predecessors of WRCs)
WiMAX	Worldwide Interoperability for Microwave Access
WRC	(ITU) World Radio Conference